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Simple tuning rules for feedforward compensators

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ABSTRACT

This paper describes new simple tuning rules for design of feedforward compensators. The problem of feedforward from load disturbances is analyzed, and it is shown that the feedback controller should be taken into account in the feedforward design process. Simple rules based on IAE minimization with restrictions on the process output overshoot and the high-frequency gain of the compensator are then derived. Several simulations are presented along the paper to show the advantages of the proposed design rules.

1. Introduction

Feedforward control from measurable disturbances provides a possibility to make control actions before any disturbance response has occurred in the process output. This fact makes it a very powerful complement to the feedback controller. Feedforward control was used as early as 1925 for drum level control in the three-element control configurations [1]. Many of the other early applications dealt with control of distillation columns [2]. In the early applications, use of feedforward was almost a prerequisite to solve the control problems in these difficult applications. Nowadays, feedforward is implemented in most distributed control systems and the technique is used also for rather simple control problems to improve the control performance.

Feedforward can also be made from the setpoint, but this problem is different from feedforward from disturbances, and it is not treated in this paper.

The basic idea for design of the feedforward compensator is very simple. The ideal compensator is formed as the dynamics between the load disturbance and the process output divided by the dynamics between the control signal and the process output, with reversed sign. If this feedforward compensator is used, the effects of the load disturbance are eliminated from the process output.

However, the ideal compensator is seldom realizable. The compensator may be non-causal, it may be unstable, it may have infinite high-frequency gain because of derivative action, and it may require a more complicated structure than what is available. These facts make the design problem non-trivial, and there is a need for design strategies and tuning rules. The design of feedback controllers faces similar problems and limitations, and there are lots of design methods for feedback controllers. It is surprising that there are so few design methods for feedforward compensators presented in the literature.

In process control, the structure of the feedforward compensator is normally either just a gain or a lead–lag filter. Sometimes a delay is also needed to ensure that the compensation is not made too early. More complicated compensator structures are uncommon.

Most basic control textbooks mention the feedforward technique, and present the design philosophy of the ideal compensator. They normally also mention the realizabililty problems, but they seldom go any further and present design rules.

In Ref. [3], a design procedure for a lead–lag compensator was proposed. The static gain of the compensator is first determined from pure static models. The gain is chosen so that a step change in the load is eliminated in steady state, without any action from the feedback controller. The time constants of the lead–lag filter are then determined with the goal to reach $IE = 0$ with minimized IAE. The effects of the feedback controller is not taken into account in the design calculations.

Ref. [1] presented a design procedure where the feedforward gain is determined in the same way as in Ref. [3]. A manual tuning procedure is then suggested to tune the time constants of the

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